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Title: LANSCE UCN Website

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Overview

LANSCE is home to one of the most intense sources of some of the coldest subatomic particles: ultracold neutrons (UCN). The LANSCE UCN source is a unique facility that produces high energy spallation neutrons and uses solid deuterium to cool the neutrons by one billion billion-fold. The resulting UCN have some unique properties that allow them to be studied precisely: they move at speeds of only a few meters per second, and are completely confined by magnetic fields and material bottles for many hundreds of seconds at a time. These properties lead to very precise *low* energy particle physics experiments that search for small differences between measurement and prediction, and these precision measurements are a powerful tool for investigating new physical processes which can complement and rival experiments at high energy colliders such as CERN.

There are several new and on-going experiments at the UCN source that measure decay correlations and other properties of the neutron. This program of measurements probes the particle physics underlying neutron decay, and has important implications for high energy physics and cosmology. In addition, because of the interaction between UCN and material surfaces, the facility is used to study materials relevant to high precision experiments, and will provide a detailed understanding of neutron induced fission on actinides.

UCNA

The UCNA experiment is the first experiment to utilize UCN for angular correlations measurements in beta-decay. UCNA was founded in 1997-1998 as a part of the already ongoing UCN program at Los Alamos, and provided the motivation for development of the production source in Area B at LANSCE. Angular correlation measurements in neutron beta-decay contribute, together with the neutron lifetime and radiative decay experiments, to a high precision determination of the parameters of the charged weak current of the nucleon. Neutron decay serves as the definitive source for some of these parameters, in particular the axial coupling constant of the nucleon, important for high precision calculations of the solar fusion rate, high precision measurements of neutrino flux and for constraints on various extensions of the standard model of particle physics. UCNA measures the beta-asymmetry, or the correlation between the neutron spin and the decay beta-particle. UCNA exploits the properties of UCN to produce a decay geometry which is competitive with more conventional cold neutron beam experiments. In particular, when coupled to the unique detector geometry for the UCNA experiment, the stored UCN produce extremely low neutron-generated backgrounds in the beta-decay detectors. UCNA was ranked as the second highest priority of the fundamental neutron science program in the Nuclear Science Advisory Committee comprehensive review of fundamental neutron science in 2011, and published an update of the beta-asymmetry with sub-1% precision in 2013.

UCNB

The UCNB experiment improves upon the spectrometer used for UCNA to investigate more correlations in neutron decay. In UCNB, the protons that are also emitted in the decay of the neutron are detected in coincidence with the decay electrons. A measurement of the electron and proton direction of emission relative to the direction of the neutron spin permits access to additional angular correlation parameters, including the proton asymmetry and the neutrino asymmetry. Recent theoretical work at LANL has provided renewed interest in the measurement of these additional parameters: these parameters are sensitive to the presence of new physics beyond the Standard Model at energy scales rivaling those probed in high-energy collisions at the Large Hadron Collider. A significant amount of new technology has been developed for the experiment such as novel, thin, pixellated silicon detectors that provide a precision measurement of the decay electron's energy. These detectors have been implemented in the UCNA magnetic spectrometer along with a 30,000 Volt accelerating electric potential that accelerates the low-energy protons for detection.

UCNτ

The half-life (or lifetime τ) of the neutron is intimately connected to many other processes in particle physics and cosmology, such as the abundance of nuclei in the early universe, neutrino physics, and when combined with neutron decay correlations, tests for new particle physics phenomena. In spite of a 60 year history of measurements, recent experimental determinations of the half-life do not agree, and new techniques and technology are being developed at LANSCE make an improved measurement. The experiment is designed to trap UCN with minimal sources of loss aside from beta decay: in this way, UCN are introduced into the trap, and the number of surviving neutrons is measured to deduce the half-life. In past "UCN bottle" experiments, material traps are used to confine the UCN which, in addition to decaying, can be absorbed or scattered by the material walls, and these material interactions must be understood carefully to determine the neutron half-life. In contrast, UCNτ uses a magnetic trap to confine the neutrons so that they do not interact with material surfaces while being stored. A 670 liter magnetic trap composed of over five thousand NdFeB magnets (the largest of its kind) was successfully commissioned in early 2013, and research and development of new UCN detection methods are underway to further improve upon previous measurements.

Actinides

While UCN are of great interest to fundamental physicists, their properties make them uniquely suited to perform detailed studies of other materials. A new program at the LANSCE UCN source uses UCN to finely control fission in actinides such as plutonium and uranium in order to investigate sputtering and damage of material surfaces, topics which are essential to the NNSA's mission. The mechanism behind material damage due to sputtering from fission is not well understood and represents one of the modern challenges facing nuclear scientists.

The novel technique of using UCN will provide a new avenue for studying the particle dynamics of material sputtering due to fission. The UCN cross-section for fission is several hundred times higher than that of thermal neutrons, and the UCN energy finely tuned via gravitational acceleration or deceleration. Their penetration depth can be adjusted to as low as a few microns, allowing very sensitive studies of the effect of material thickness, or the properties of oxide layers on the surface. From the morphology and distribution of sputtered atoms ejected from the material, we will insight into the underlying process and resolve questions about competing theoretical models. This work is supported by the G. T. Seaborg Institute for Transactinium Science and the U.S. Department of Energy through the LANL/LDRD Program.

nEDM R&D

An electric dipole moment (EDM) measures the separation of positive and negative charges within a system and is an extremely sensitive probe of physics beyond the standard model. A new neutron EDM (nEDM) experiment is being developed to be installed at the Fundamental Neutron Physics Beamline (FnPB) at the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory, with a goal sensitivity of $\delta d_n \sim 5 \times 10^{-28}$ e-cm, an improvement of two orders of magnitude over the current limit set by an experiment at ILL. Based on a method proposed by Golub and Lamoreaux, this experiment will be performed in a bath of superfluid liquid helium at 0.4 K. LANL is leading several important R&D efforts. One of them is development and testing of UCN storage cells. UCNs from the LANSCE have been used to test prototype UCN storage cells.

Electric dipole moment

A new effort is under way at LANL, taking advantage of the unique LANSCE UCN source, to develop a room temperature nEDM experiment with a sensitivity of $\delta d_n \sim 3 \times 10^{-27}$ e-cm, a 10 fold improvement over the current limit set by an experiment at ILL. This work is supported by the LANL/LDRD program. The work includes an upgrade of the UCN source and prototyping of a new nEDM experiment apparatus.

The short term goal (FY14-FY16) is to demonstrate storage of the number of UCNs sufficient for a $\delta d_n \sim 3 \times 10^{-27}$ e-cm experiment in a realistic nEDM prototype apparatus.

UCNb

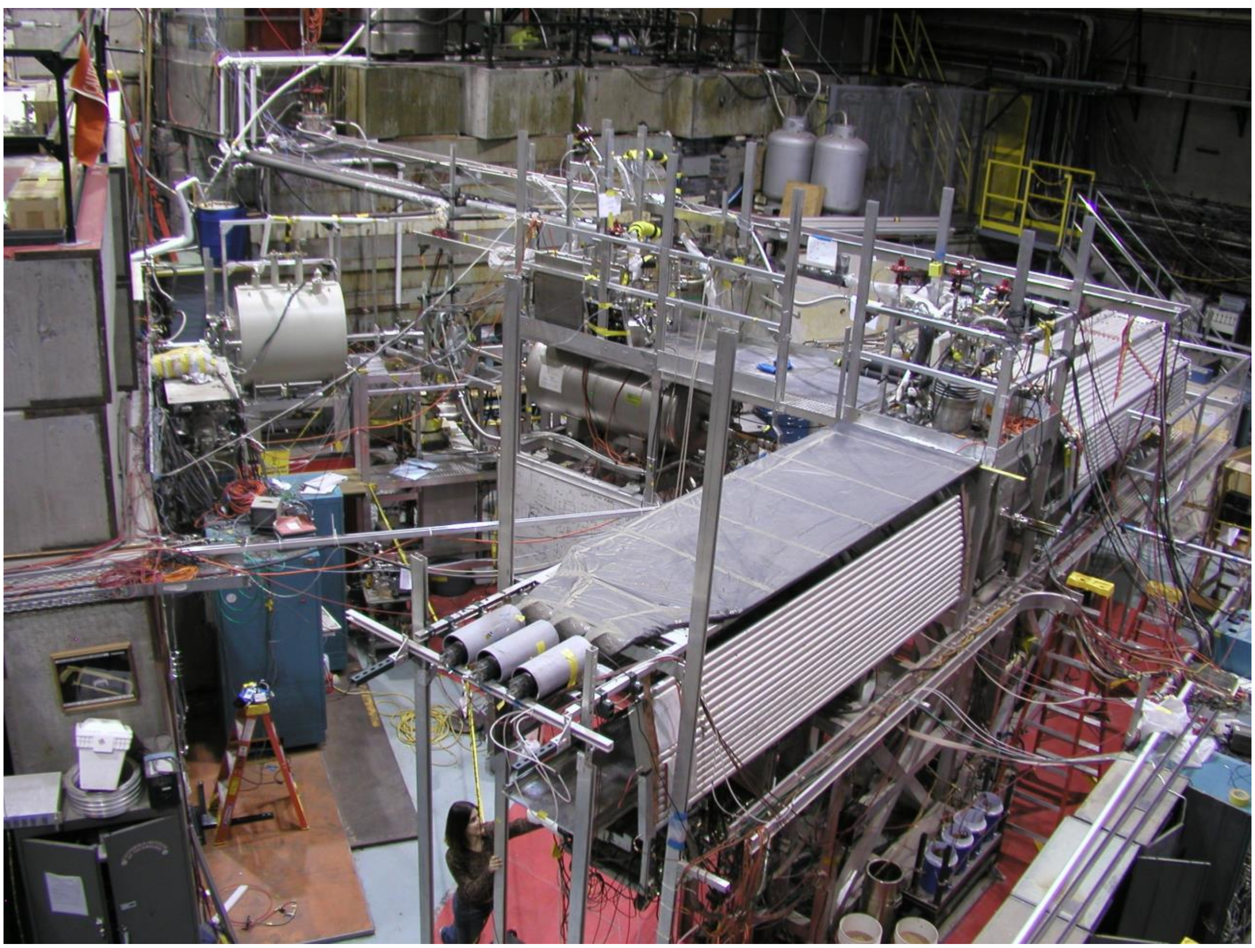
Recent Publications

E.I. Sharapov et al. Upscattering of ultracold neutrons from the polymer $[C_6H_{12}]_n$.Phys. Rev. C **88**, 064605 (2013).

E.I. Sharapov et al. Measurements of ultracold neutron upscattering and absorption in polyethylene and vanadium. Phys. Rev. C **88**, 037601 (2013).

M.P. Mendenhall et al. Precision measurement of the neutron β-decay asymmetry. Phys. Rev. C **87**, 032501 (2013).

A. Saunders et al. Performance of the Los Alamos National Laboratory spallation-driven solid-deuterium ultra-cold neutron source. Rev. Sci. Instrum. **84**, 013304 (2013).

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